Renewable and Sustainable Energy Reviews 18 (2013) 73–86

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Current status, future potentials and challenges of renewable energy development in Gansu province (Northwest China)

Wu Yunna, Xu Ruhang *

School of Economics and Management, North China Electric Power University, Beijing 102206, China

ARTICLE INFO

Article history:
Received 14 April 2012
Received in revised form
25 September 2012
Accepted 30 September 2012
Available online 3 November 2012

Keywords:
Northwest China
Gansu
Renewable energy
Review
Market development
Technology development

ABSTRACT

Gansu province is relatively less developed in economy, whereas abundant in Renewable Energy Sources (RES). It has been counting on heavy industry for a long time and highly dependent on fossil fuels, causing serious pollutions. Meanwhile, its own power demand is insufficient, thus its RES-generated electricity must be out-delivered. After the Renewable Energy Law (REL) took effect in 2006, RES development is booming in this area, bringing about a series of problems as well. This paper aims to present the current status, future potentials and challenges in Gansu by carrying out a detailed review of relevant studies, along with surveys on the wind and solar developers. Particularly, Gansu is a typical province in terms of RES development in Northwest China. It can be concluded that the RES development in this district is policy-driven to avoid risks in technology cost efficiency, grid co-development and so on.

Contents

* Correspondence to: School of Economics and Management, North China Electric University, Zhu Xin Zhuang, Beijing 102206, PR China. Tel.: +86 15010066179.
E-mail address: sdxu8888@gmail.com (X. Ruhang).

1364-0321/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.rser.2012.09.038

1. Introduction

At the end of 2009, the Chinese government made a political commitment to the international community at the Copenhagen Conference on climate change that China's greenhouse gas emission control target until 2020 is a decrease of CO_2 emissions per unit GDP by 40%–45% to that of 2005, which is also considered as a mandatory indicator in its medium and long term economic and social plans. In China, there has been a contradiction between economy growth and energy supply for a long time, the solution to which is to find a path to keep resources and consumption in a sustainable equilibrium. The northwest district of China is relatively less developed, whereas it is rich in RES, hence the development status of renewable energy in this district is with high reference value to China's sustainable development.

The northwest district of China in this paper refers to Gansu, Ningxia, Qinghai, Xinjiang, northern Shanxi and western Inner Mongolia. From climate aspect, they all have a continental monsoon climate of medium latitudes, and the precipitation decline from east to west and from south to north. Topographically, the landform mainly consists of plateau and basin, while specifically from east to west includes: steppe, desert steppe, desert and plateau. Moreover, the economy development is nearly at the same level in these areas. After the launch of REL in 2006, the utilization of renewable energy in this district is booming, in particular wind and solar power. Meanwhile, the Chinese central government has drawn up several plans to promote renewable energy in this district, including the plan of constructing large wind power and solar power electricity generation bases, and the plan of enhancing rural area residents' living standard by means of energy transformation using hydropower, solar and biomass energy.

Many researches attempt to throw light on the problems of renewable energy development that China has encountered in recent years; however the reality is so complicated that the influencing factors vary from area to area due to China's vast territory. Therefore, this paper aims to draw a miniature of renewable energy development in northwest district through a review of related researches on Gansu province, and to illustrate the major contradictions it faces in renewable energy development.

Gansu province owns an area of 0.45 million km^2 in total, and is located from 32°31′N to 42°57′N and from 92°13′E to 108°46′E. Its population density is 87.6 pop/km^2, while its GDP growth rate exceeded 10% every year in the period of 2003–2010 and reached a new high record of 12.3% in 2007 [1].

Nevertheless, Gansu has a weak ecological environment. First of all, water resource is scarce and unevenly distributed. The amount of self-produced water resource totals 29.5 billion m^3, while per capita share is merely 1150 m^3 which is less than half that of China's national level. Secondly, low in forest coverage rate and severe in soil erosion, Gansu is confronting an increasingly grievous situation of desertification and soil salinization. Its desert areas and desertified land mainly distributed in the Hexi Corridor[1] plain and North Mountain region[2]. Finally, the degeneration of steppe is severe. The natural grassland is about 0.17 million km^2, which is 36.62% of the total land size, but now 90% of them are undergoing degeneration at different degrees [2].

2. Energy consumption and pollution

Fig. 1 shows the economy development status of Gansu, while Table 1 presents its energy consumption over the years. During the early years of PRC, the central government adopted the strategy of "using western resources to support national construction". With a powerful investment impetus from the central government, Gansu's industrialization went through rapid but unreasonable soar, during which the second industry's economic growth is rather notable. Specifically, in the period of 1969–1979, 1979–1989 and 1989–1999, the economic growth rate of Gansu achieved 148%, 222% and 330% respectively, while heavy industries such as oil, non-ferrous metal, steel and chemical

[1] A long and narrow corridor-like flat land, which is in the trend of northwest to southeast and about 900 km long as well as 100 km wide. Specifically, it starts east from Wushaoling and reaches west to ancient Yumen Pass, it is located between the North Mountain and the South Mountain (Qi lian, A erjin). It is also called Hexi Corridor because it is located in the west of the Yellow River.

[2] The mountain range including Mazong Mountain, Heli Mountain and Longshou Mountain. Its length in east–west direction is about 1000 km.

contributed the most. Nowadays, the heavy industry still accounts for a large percentage of the total energy consumption, and it is heavily dependent on fossil fuels. The energy consumption of various sectors in 2009 is shown in Table 2 [3].

Similar to other western provinces of China, Gansu demands a large amount of outer investment owing to its lesser developments. Nevertheless, outer capitals always focus on high pollution and energy-consumption industries like mining and manufacture, which would lead to the Pollution Haven Effect [4]. Moreover, most Gansu's farming areas lack water, thus long-term irrigation and pesticide use results in heavy metal pollution, while traffic and transportation also exerts negative influence on it [5].

In recent years, there exist a great number of ecological deficits in Gansu province. The demand of fossil fuel ranks first among all sorts of productive land needs, which indicate that energy demand's great pressure on the sustainable development of ecological economy serves as a major trigger of ecological deficit [6]. Hence, adjusting the energy supply structure and reducing reliance on fossil fuel have a worthy implication for the sustainable development of Gansu province.

3. The status of RES in Gansu

3.1. Wind energy

Wind energy resources are particularly abundant and with good prospects for developing in Gansu province. According to relative report, it enjoys a theoretically overall wind reserve of 237,000 MW and a technically exploitable of near 40,000 MW, ranking the sixth in China. Given the fact that the spatial distribution tends to be declining from northwest to southeast in Gansu, areas with high potential mainly are throughout Hexi Corridor region. Besides, western region and certain mountain areas have an annual average effective wind energy density of above 200 W/m^2, while the number of effective wind speed hour can reach over 6000. Located in the west part of Hexi Corridor,

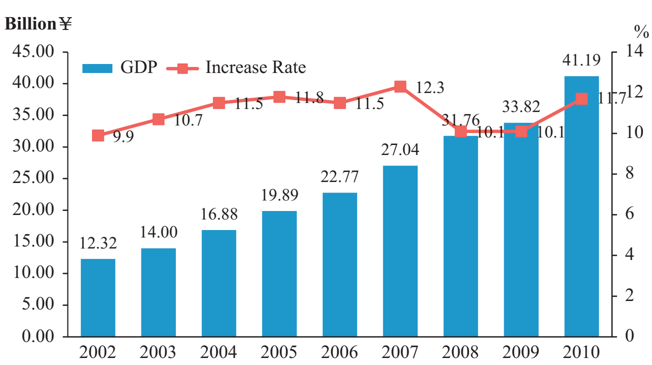

Fig. 1. Year-wise evolution of GDP in Gansu and its increase rate [1].

Jiuquan area serves as the most high-value center of wind resources with a total wind reserves of 150,000 MW, while its theoretically exploitable quantity accounts for more than 85% that of Gansu. Hence, Jiuquan is identified as the national Class II wind resource area.

Distributing in Hexi region, areas like Guazhou, Jinta, Yumen, Wushaoling and Huajialing occupy 23% of the provincial size and have an average wind speed of above 4 m/s. Especially in several parts, the wind speed is stable and enjoys a small annual change, which is extremely beneficial to the utilization of wind power. Yumen town is adjacent to Xinjiang and Inner Mongolia which are most abundant in wind energy, therefore it can enjoy approximately 300 days of wind available time every year. Additionally, other areas whose annual average wind speed are above 3 m/s include Anxi, Mingle, Yongchang, Gulang, Tianzhu and so on, while most of them are qualified to build large-scale wind power plant. The distribution of wind resource in Gansu is presented in Fig. 2 [7].

3.2. Solar energy

In Gansu province, extremely large solar energy resources also exist in some of its remote regions. The total quantity of radiation in Gansu reaches as high as about 4800–6400 MJ/m^2 per year, and the sun shines 1700–3300 h annually, meanwhile the spatial distribution tends to be declining from northwest to southeast. In particular, Hexi region has an annual radiation of 5800–6400 MJ/m^2 which is 700–1000 MJ/m^2 more than that of the eastern China at the same latitude, while the sun shines 2800–3300 h per year.

Additionally, long in sunshine time and high in atmosphere transparency, as well as flat in topography, some desert areas located in northern and central Gansu are also suitable for solar energy development. In fact, the annual total radiation in northern, central Gansu and desert areas can reach 6680–8400, 5850–6680, and over 6000 MJ/m^2, which in reverse verifies the abundance of solar energy throughout Gansu province owing to its unique geographical location and condition. The distribution of solar resource in Gansu is presented in Fig. 3 [8,9].

3.3. Hydropower

Gansu province is categorized into three river basins, namely the Inland River, Yellow River and Yangtze River, which then include twelve water systems. In detail, the Inland River consists of three water systems of Sule River, Hei River and Shiyang River; the Yellow River contains six water systems of Huangshui, Tao, Jing, Beiluo, Wei, main Yellow River and its tributaries; while the Yangtze River includes three water systems of upstream of Jialingjiang, Bailongjiang, Xihanshui. There are 78 rivers whose annual runoffs exceed 100 million m^3, among which 15, 36 and 27 rivers respectively belong to above-noted three river basins.

Table 1
Energy consumption details over 2005–2009 [3].

Item[a]	2005	2006	2007	2008	2009
Total energy available for consumption	43.68	47.43	51.09	53.46	54.82
Primary energy output	36.05	37.99	39.86	40.69	42.32
Recovery of energy	1.34	1.48	1.36	1.29	1.68
Imports	27.93	27.91	29.75	34.76	35.19
Exports (-)	−21.24	−19.95	−19.69	−20.83	−24.49
Stock changes in the year	−0.40	0.01	−0.18	−2.44	0.11
Total energy consumption	43.68	47.43	51.09	53.46	54.82

[a] Unit: Mtoe.

Table 2
Energy consumptions of various sectors in 2009.

Sector	Agriculture, husbandry	Industry	Construction	Transport	Sale, catering	Residential consumption
Total[a]	2.65	40.22	0.71	3.64	0.69	5.82
Coal[b]	43	3870.5	25	53	28	439.5
Coke[b]		540.33				
Crude[b]		1440.79				
Gasoline[b]	3.2	7.04	8.2	17.5	3.9	3
Kerosene[b]	0.02	0.14	0.02	5.24	0.01	0.01
Diesel oil[b]	27	22.32	10.5	121.96	1.8	0.24
Fuel oil[b]		13.39				
Liquefied[b] petrol gas[b]		0.1		0.7	0.09	5.53
Natural gas[c]		9.62	0.03	1.3	0.49	0.78
Electricity[d]	56.38	534.43	5.83	28.92	10.12	46.33

[a] Unit: Mtoe.
[b] Unit: 10,000 t.
[c] Unit: 100 million m^3.
[d] Unit: 100 million kWh.

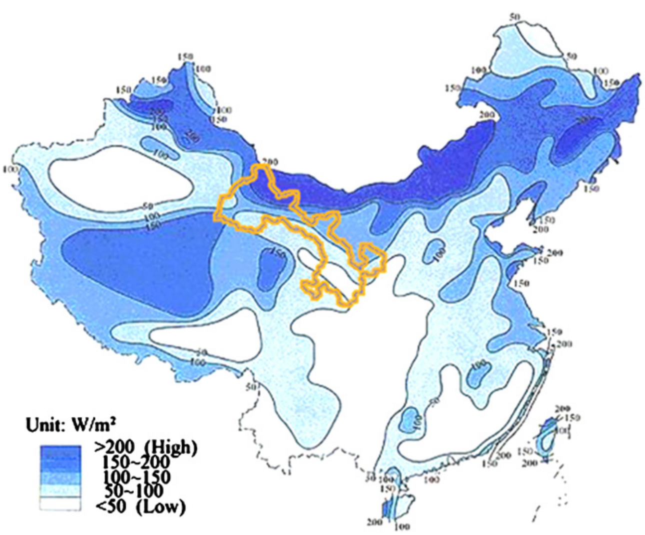

Fig. 2. The distribution of wind resource in Gansu [7].

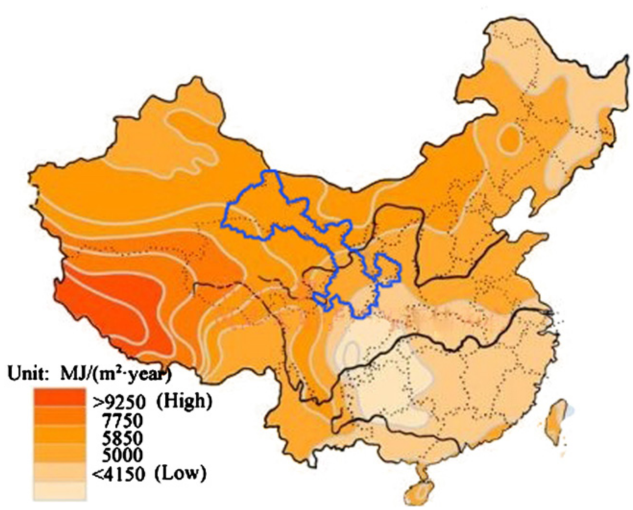

Fig. 3. The distribution of solar resource in Gansu [8].

Moreover, Gansu's total water resources reach 61.15 billion m^3, 28.21 m^3 of which is self-produced surface water resources. In addition, it enjoys a theoretically overall hydropower reserve of 18.13 million kW, and a technically exploitable of about 12.05 million kW which includes 4 and 3.96 million kW of medium and small-sized hydropower respectively. The theoretically overall water reserve and technically exploitable amount of the Inland River, Yellow River and Yangtze River reaches respectively 3.33, 2.05; 9.82, 7.42; and 4.98, 2.58 million kW [10].

Table 3
The production of major crops from 2005 to 2009.

Kind[a]	2005	2006	2007	2008	2009	Average
Wheat	264.84	260.70	237.42	268.10	261.10	258.43
Com	248.51	218.60	242.65	265.40	312.60	257.55
Tubers	189.87	187.95	206.64	214.60	191.40	198.09
Beans	41.65	39.46	35.61	36.76	33.71	37.44

[a] Unit: 10,000 t.

3.4. Biomass energy

3.4.1. Biomass liquid fuels

At the moment, resources with great potential for biomass liquid fuels mainly contain sweet sorghum, sweet beet, xanthoceras sorbifolia, oil sunflower, as well as several other energy plants such as tung oil trees, wild walnut and so on. It is noteworthy that oil sunflower is a good choice for biodiesel due to its amazing oil percentage (65%–70%), and it is also highly drought resistant, as well as barren and salinity resistant. Benefitting from Gansu's long sunshine time and high altitude, along with large day–night temperature difference, above-mentioned plants are suitable to cultivate here.

3.4.2. Biomass waste resources

Gansu is a major agricultural province who is most productive of potatoes thanks to its favorable conditions. The production of major crops from 2005 to 2009 is presented in Table 3. Furthermore, averagely, there are about 10 million tons of straw left, and the industrial process of potato and apple can leave respectively 0.3 and 0.15 million tons of residues [3,11].

4. Related policies

4.1. National objective

The central government planned to achieve a 5 GW total installed capacity of wind power generation by 2010, which

concentrate in the eastern coast and "North Three"[3] areas and consist of about 30 large wind power projects at 100 MW-scale. Furthermore, it is projected to reach 30 GW by the end of 2020, and at that time six large-scale wind power bases at 1000 MW-scale will be built.

Total electricity generated by solar energy is projected to reach 300 MW by 2010, and this is expected to increase to 1.8 GW by 2020. To achieve the objectives, on the one hand, household PV power generation systems as well as small PV power plants are programmed to be established to handle the electricity supply issues of villages and rural residents in remote areas, in particular Tibet, Qinghai, Inner Mongolia, Xinjiang, Ningxia, Gansu, Yunnan and so on. On the other hand, solar integrated construction and central solar heating water project should be promoted and popularized in urban areas, together with several solar heating and cooling demonstration programs. For instance, during China's 11th Five year Plan, demonstration projects of large grid-connected solar PV power plant are about to set up in Dunhuang (Gansu) and Lasa or Ali (Tibet).

In regions with abundant hydropower resources, small hydropower resources should be exploited at a higher speed, together with the construction of rural electrification county as well as "small hydropower instead of fuel" project. By 2010, national overall hydropower installed capacity is planned to be 190 million kW, among which large and medium-sized account for 140 million kW. In comparison, it will be 300 million kW by the end of 2020, 225 million kW of which is large and medium-sized hydropower. The west part of Gansu province belongs to the upstream of the Yellow River, hence it is within the planning area of national focus on the development of hydropower.

Concentrations will be put on the development of biomass, biogas, biomass solid fuel and bio-liquid fuel. By 2010 and 2020, the total installed capacity of biomass electricity generation will be 5.5 and 30 GW, while the annual use of biomass solid fuel, biogas, bio-fuel ethanol and bio-diesel are respectively to be ranging from 1 to 50 million tons, 19–44 billion m^3, 2–10 million tons and 0.2–2 million tons [12].

4.2. Renewable energy concession project

The Chinese Center for Renewable Energy Developments (CRED) has created a "Renewable energy concession" approach. Initially, on the basis of investigation and measurement, local government designates a specific region which is of promising commercial exploitation value and the capability to install the appropriate scale of renewable energy generators. Then, through an auction involving buying and selling of the ownership and management rights of specific region, the private developer who wins the bid becomes the owner, and also should be responsible for all the investments and risks during construction and operation according to reached provisions.

During the concession, the government should keep the promise to purchase all the electricity generated from renewable energy resources of this project, thus local grid management department and the owner should sign a power purchase contract whose duration must be longer than the project's operation period and in which the electricity price is determined by bidding price. Besides, the concession period is usually 20–25 years, so the owner should unconditionally hand over the ownership and management rights of overall project assets to local government or designated agent after the deadline.

[3] Refers to Northeast China, Northwest China and North China.

4.3. Renewable energy tariff surcharge

REL formulates that the exceeded part of the purchasing price of renewable energy generated electricity compared to the average feed-in tariff of conventional energy should be allocated in electricity sales price. The imposing standard of renewable energy tariff surcharge was initially set at 0.002 ¥/kWh, which was adjusted to 0.004 and 0.008 respectively in November 2009 and January 2012. The exceeded income from this surcharge should be used for the special fund of renewable energy development, which is primarily used to support the following activities:

- The scientific and technological research, relative standard formulation and demonstration projects which include renewable energy exploitation.
- The renewable energy exploitation projects for living energy use in rural and pastoral areas.
- The construction of independent power systems of renewable energy in remote areas and islands.
- The resource exploration and evaluation of renewable energy and corresponding information system construction.
- Promoting the localization of the manufacture of equipment used in renewable energy development and utilization [13].

4.4. Feed-in tariff policy

4.4.1. Wind energy

Before 2005, the cumulative wind energy installed capacity in China is relatively little in total. In the period of 2005–2009, China implemented the wind power feed-in tariff pricing measure in two main ways, namely the local franchise bidding plus central approval as well as central bidding, which set price respectively at 0.51–0.65 and 0.4–0.55 ¥/kWh. After 2009, wind power feed-in tariff is set at fixed price determined by the situation of various wind power resource areas, under which condition the price is between 0.51 and 0.61 ¥/kWh.

4.4.2. Grid-connected solar energy

The development of solar energy electricity generation lags behind that of the wind power. Its feed-in tariff pricing measure also includes central bidding and local franchises bidding accompanied by central approval. Particularly, the feed-in tariff price of PV power generation in Shanghai, Inner Mongolia and Ningxia was set at 4 ¥/kWh in the year of 2008 and 2009, while that of Dunhuang 10 MW PV project was 1.09 ¥/kWh in 2009; in April 2010, the price of four temporarily grid-connected projects in Ningxia was set at 1.15 ¥/kWh; the winning bidding price of 13 projects in northwest China achieved between 0.729 and 0.990 ¥/kWh in September 2010. Additionally in August 2011, the National Development and Reform Commission (NDRC) announced to set the unified feed-in tariff of PV power projects which were approved before 1st July at 1.15 ¥/kWh, and that of PV power projects which were approved after 1st July at 1 ¥/kWh.

4.4.3. Hydropower

At present, the feed-in tariff of hydropower does not employ the national preferential policy for renewable energy, but is determined by different levels of price management department based on the cost, profit, taxation and supply capacity of a power generation station. This pricing method suffers great negative comments. Taking a small hydropower station in Hunan as an example, its total electricity supply in 2010 was 148,728 kWh whereas the corresponding charge was ¥28753.7, equivalent to only 0.193 ¥/kWh. Meanwhile,

after the first commercial operation of the Three Gorges project in June 2011, its feed-in tariff was set at about 0.251 ¥/kWh [14].

4.4.4. Biomass

The feed-in tariff of biomass electricity power generation project is decided by the central government. In detail, the Pricing Department of the State Council formulates various benchmark prices for every individual area, which consists of the benchmark price of desulfurization coal-fired units (including autonomous region and municipality directly under the central government) of each province in 2005 together with price subsidy. Besides, the standard price subsidy is 0.25 ¥/kWh, while it can be enjoyed by a biomass project for 15 years after its commercial operation. As of 2010, the price subsidy of newly approved projects will be progressively reduced by 2% every year. For those projects whose developers are determined via bidding, their feed-in tariffs are decided by the winning bidding price which cannot exceed the benchmark price of every individual area [15].

4.5. Subsidy policy

In principle, all renewable energy power generation projects can enjoy national price subsidy for feed-in tariff, while the specific amount depends on situations.

In March 2009, the Ministry of Finance (MF) together with the Ministry of Housing and Urban-rural Construction (MHUC) declared *the implementation opinion on accelerating the application of solar PV power constructions*, based on which the qualified demonstration projects can be subsidized by special fund to compensate for initial investment. At the same time, the MF introduced *the temporary management method of financial support for solar power construction application*, principally determining the standard price subsidy to be 20 ¥/Wp [15,16].

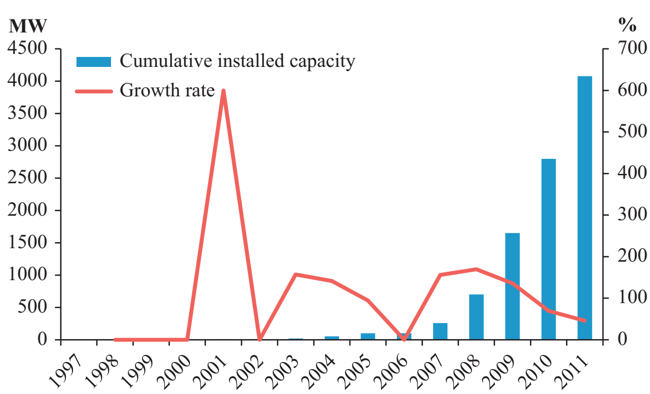

Fig. 4. The cumulative installed capacity and growth rate of wind power.

In July 2009, the MF, the Ministry of Science and Technology (MST) along with the National Energy Administration (NEA) announced *the temporary management method of price subsidy for Golden Sun demonstration projects* to focus on supporting PV power plants, offering a subsidy of 50% and 70% respectively for gird-connected and standalone PV power systems [17].

Apart from direct financial subsidy, tax preference serves as a sort of indirect subsidy. In September 2008, the MF coupled with the State Taxation Administration introduced *the notice on the implementation of tax preference directory for resources comprehensive utilization enterprises*, giving 90% off in Value Added Tax (VAT) for proper enterprises. At the same year in December, they then announced *the notice on resources comprehensive utilization and the VAT policy of its production*, giving 50% off in VAT for wind power generated electricity and biomass generated diesel.

The MF declared *the temporary management method of special fund for the industrialization of wind power generating equipment*, deciding to offer reward instead of subsidy for wind power generating equipment to support its industrialization and core technology development. On the foundation of proposed method, qualified enterprises' first 50 wind power units at the size of MW should be supported at the standard of 600 ¥/kW, while machine manufacturing enterprise and core component manufacturing enterprise each accounts for 50%. Since January 1st 2008, the import tariffs and VAT of core component or raw materials that are imported for exploiting and manufacturing high-power wind turbine unit should implement rebates.

The implementation of above-noted policy is facing a difficult time in that its effect is unsatisfied and China is undergoing trade conflicts with countries like the USA [18].

4.6. Other polices

The Chinese government has been levying the resource tax on fossil energy extraction since 1984. On the 21st September 2011, it decided to adjust the tax imposing method from amount-based to price-based, therefore to increase the cost of fossil energy sector. Furthermore, it also programs to levy the carbon tax on fossil energy users after the year 2012, which may be imposed on the basis of a fixed rate and levied by the amount. Undoubtedly, these policies show beneficial messages for renewable energy due to its substitution effect of conventional fossil energy.

Table 4
The cumulative installed capacity of each wind power developer.

Company Name	Installed capacity(MW)[a]	Share (%)
China Longyuan Power Group CO. LTD.	841.3	20.63
China Huaneng Corp.	501.5	12.30
China Power Jiuquan Wind Power CO. LTD	450	11.04
China Energy Conservation and Environmental Protection Group (CECEP)	400	9.81
China Huadian Corp.	396	9.71
China Datang Corp.	387.8	9.51
State Development & Investment Corp (SDIC)	300	7.36
Shandong Luneng Group CO. LTD.	201	4.93
Hong Kong Construction (HKC)	201	4.93
China Resources Company (CRC)	201	4.93
China Guangdong Nuclear Power Group (CGN)	148.5	3.64
Tianrun New Energy Investment CO. LTD.	49.5	1.21

[a] Including accomplished but not operated ones.

5. The development status of RES in Gansu

5.1. Wind energy

5.1.1. Governmental development plan

During the China's 11th Five year Plan (2006–2011), the provincial government of Gansu intended to newly build nineteen 200 MW-scale wind farms whose total installed capacity will reach 3.8 GW. During the China's 12th Five year Plan (2012–2017), the government programs to construct wind farms with a whole installed capacity of around 8 GW, and by the end of 2015 to form a 10 GW-scale wind power base. Furthermore, Gansu province has set specific targets for wind power installed capacity of 10.88 GW by 2013 as well as 15.98 GW by 2015, of which Jiuquan area alone may contribute 9.58 GW and 14.48 GW respectively. In addition, to be in line with the rise of wind power installed capacity, the government decided to start a 750 kW supporting transmission line project which will correspondingly establish thirteen 330 KV step-up substations [19].

5.1.2. Wind turbine technologies

Benefitting from current government-favorable trend of wind power industry, China's domestic wind turbine manufacturers have been developing successfully. For now, three large enterprises, namely Huarui Corporation, Jinfeng Company and Dongqi Company, rank the top three in both cumulative and newly installed capacity in China [20]. In Gansu province, several former wind power bases adopted import wind turbine. For example, Longyuan Group used four 300 kW wind turbines from Denmark's Nortank Corporation when it was developing the 1.2 MW demonstrative wind farm in 1997; it also adopted 58 wind turbines at the size of 850 kW from Spain's Gamesa Corporation when establishing the 49.3 MW Yumen wind farm in 2007. Apart from this, most wind power developers are inclined to utilize domestic wind turbines, which positively reduces the cost of wind power generation and also enhances the competitiveness of wind power.

Chinese current technologies of wind turbine indicate that the major tendency will be the larger size of wind turbine power. Among the wind turbines that are already in operation, the type of which is three-bladed, up-wind, dual-fed, speed-variable, and frequency-constant with pitch and horizontal-axis still plays the dominant role. In order to meet the development needs of national Class II and III wind resource areas, domestic enterprises now adopt bigger wind wheel diameter than before.

5.1.3. Development status

This paper carried out exclusive statistic survey targeting wind power developers in Gansu region, while the collected installed capacity ignored the wind power projects which already signed an agreement but not yet started construction, whereas included the ones which were accomplished but not yet grid-connected. By 2012, there are 12 enterprises that have already formed a certain scale of installed capacity. The cumulative installed capacity and growth rate of wind power is shown in Fig. 4. The cumulative installed capacity of each developer can be seen in Table 4.

As of February 2012, Gansu's total wind power installed capacity reaches 4000 MW. Its growth rate curve hit a record high in 2001 in that there was merely one 1.2 MW wind power demonstration project in Gansu before 2001, whereas Longyuan Group carried out some technological transformation which increased the installed capacity to 7.2 MW. Therefore, it can be concluded that Longyuan Group began to develop wind power in Gansu in an early year, which is conductive to accumulate technology and experience and makes it accounting for 20% of Gansu's overall wind power market. In addition, Longyuan Group now ranks the world third in wind power installed capacity, preceded only by Spain's Iberdrola Power Corporation and America's Next Era Energy Resource Corporation.

Prior to 2006, there were only two enterprises developing wind power in Gansu, namely the Longyuan Group and Datang Corporation. Nevertheless, after the promulgation of REL at the same year, China enacted a series of national policy for renewable energy such as tariff and financial subsidy, which have been effective in driving Gansu's growth rate curve of wind power installed capacity to a third new high. Meanwhile, Gansu's cumulative installed capacity also enjoyed an amazing rise in

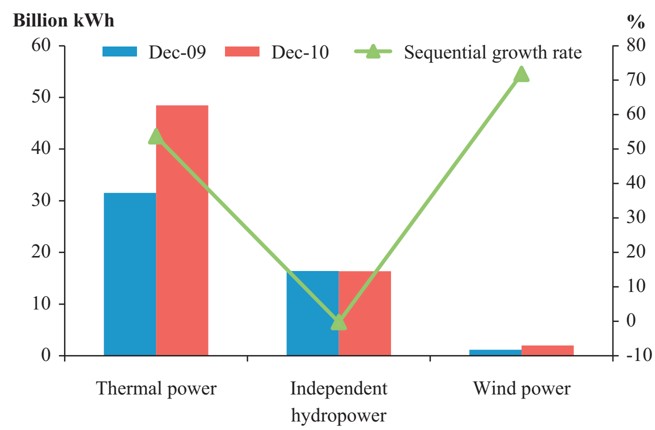

Fig. 5. Sequential comparison of 2009 and 2010 on electricity generation [21].

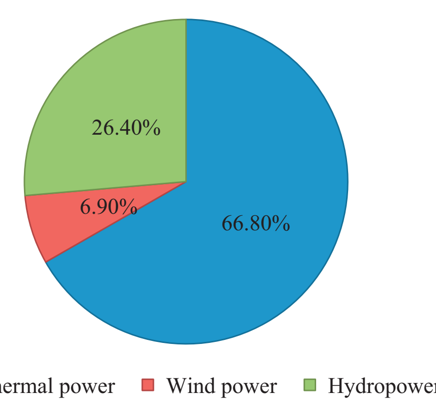

Fig. 6. Grid-dispatching installed capacity ratio of different energy sources [21].

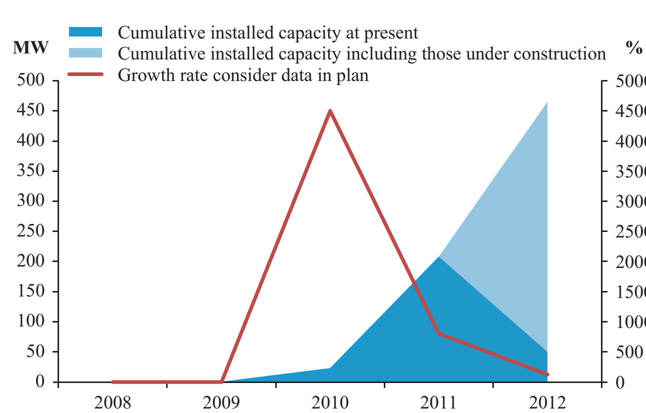

Fig. 7. The cumulative installed capacity and growth rate of solar power.

that another 10 wind power developers joined the industry during this period.

As shown in Fig. 5, according to the statistics of Gansu Grid Company, the provincial electricity generation from wind power in December 2010 had increased 71.83% compared to that of one year ago. What's more, the grid-dispatching installed capacity ratio of wind power contributes 7% that of all the energy as shown in Fig. 6 [21].

5.2. Solar energy

5.2.1. Grid-connected power generation

During the China's 12th Five year Plan, the central government has a target of installing 10 GW of grid-connected solar generation capacity by 2015. According to current plan, it is made up of three parts, including about 6.5 GW of large-scale solar power plant, 3 GW of distributed PV projects, together with 0.5 GW of off-grid solar system which are primarily employed in remote power shortage areas. In particular, the first part is projected to start solar power bases in Qinghai, Xinjiang and Gansu, meanwhile give impetus to major large-scale power generation projects in Inner Mongolia, Ningxia, Shanxi and Tibet. The second part concentrates on central and eastern part of China where serves as the energy consumption center and then arranges projects on the basis of electricity consumption indicators.

In 2006, Gansu's provincial government set up the International Solar Technology Promotion and Transfer Center of United Nations Industrial Development Organization (UNIDO), which would provide technological foundation and support for solar power generation industry. Then in the year of 2008, the Wuwei solar power plant of Datang Corporation finished the phase one project and put it into operation with an installed capacity of 500 kW, which is the first desert grid-connected PV power plant in China. Afterwards, a 10 MW PV power generation project in Dunhuang began to construct in 2009, and it was accomplished two years later with a determined tariff of 1.09 ¥/kWh, which is the first concession project of grid-connected PV power generation in China. What's more, the Jiayuguan PV power project of Huadian Corporation accomplished its phase one project at a size of 10 MW.

(1) Photovoltaic technology

There are generally two types of solar cell technology, namely the crystalline silicon wafer technology and the thin film cell technology. The former one can be divided into single as well as multi-crystal silicon cells, while the latter includes mature technologies such as CdTe cell, CIGS cell and amorphous silicon.

The development level of different solar cell technologies varies. On a global scale, crystalline silicon cells are mature and have been penetrating the PV market rapidly in the past few years, accounting for over 80% of the commercial solar cells while even reached 86.1% in 2010. On the other hand, thin film cell technology also revealed a great growth and potentially a greater development in the period of 2006–2009, among which CdTe cell had made rapid progress in particular while CIGS cell and amorphous silicon as well as less matured technologies like dye sensitized solar cells and its derivatives developed relatively slowly [20].

When it comes to Gansu province, the majority of its grid-connected PV stations are deployed with crystalline silicon cells. Besides, localization of the manufacture of solar cells cuts down the cost in a large extent, which can be verified by the fact that the bid prices of 13 PV power generation projects in northwestern China are as low as 0.73–0.99 ¥/kWh. It is sheer possible that the price of solar cells will continually go down with ever-increasing expansion of productivity as well as intense competition.

(2) Solar Thermal Power technology

Solar Thermal Power (STP) is often called Concentrating Solar Power (CSP) system, and they produce electricity in much the same way as conventional power stations. The difference among them is that CSP plants obtain their thermal energy by concentrating solar radiation in different ways, and converting it to high-temperature steam or gas, which then drives a turbine or motor engine. At the moment, CSP technologies can be sorted into three categories, namely parabolic troughs, power towers, and solar dish systems.

Roughly speaking, solar trough power system uses a parabolic mirror to concentrate the Sun's rays onto a receiver tube, during which the solar radiation conversely warms up the heat transfer fluid flowing through the receiver tube to produce steam which then drives a conventional turbine/generator to produce electricity. Power towers consist of many heliostats that concentrate the incoming direct-beam radiation to a receiver (sun boiler) located at the top of a tower, during which the radiation directly superheats the heat substance or heats the water in the receiver to produce steam which in turn drives the turbine/generator. Solar dish systems use a two-axis parabolic dish to focus sun radiation into a cavity receiver where it is absorbed and transferred to a Stirling heat engine/generator.

At present, the parabolic troughs technology is adopted by merely two developers in Gansu, namely the 10 MW project of Datang Corporation in Tianwei and the 50 MW project of Huadian Corporation in Jinta.

(3) Development status

On the basis of the exclusive investigation of this paper, we can see that as many as 22 developers are carrying out solar power generation exploitation now in Gansu, most of whose capacity are under construction in 2012. Datang Corporation was the pioneer in this industry here who separately established two PV power projects in size of 0.5 MW in 2008 and 2009. Nevertheless, enterprises and developers flooded into this industry during the year of 2010–2011, which made the growth rate of solar power installed capacity achieved an 800%. The cumulative installed capacity and growth rate of solar power is shown in Fig. 7. Unlike wind power generation, a large number of upstream suppliers also took part in the construction of solar plants. The installed capacity status can be seen in Table 5.

Several contributors to this unprecedented boost of solar power generation in Gansu include following issues. Initially, overseas market's demand for PV products presented an evident decline owing to the outbreak of global financial crisis in 2008, thus resulting in unmarketable PV products of domestic manufactures and forcing them to shift the investment. Secondly, China has successively launched a series of solar power projects which also encourage the industry, such as demonstration projects of solar power generation used in urban and rural constructions, large-scale grid connection demonstration projects of solar energy, together with "Golden Sun" demonstration project. Thirdly, in March 2009, Chinese government introduced a grid-connected PV power concession program of demonstration projects in size of 10 MW at Dunhuang [22]. Furthermore, solar power developers and the local government have reached an agreement that Gansu's solar power installed capacity will total over 3000 MW by the end of 2015. Several primary power generation bases of wind and solar energy are illustrated as in Fig. 8 [23].

Table 5
The installed capacity of each solar power developer.

Company name	Installed capacity (MW)
China Power International New Energy Holdings LTD.	100 (under construction)
CHINT Group Corp.	100
Power Construction Corporation of China	50 (under construction)
Guangdong No.2 Hydropower Engeneering Bureau CO.LTD.	50 (under construction)
China Huadian Engineering CO.LTD.	50 (under construction)
Shanghai Aerospace Automobile Electromechanical CO.LTD.	48 (under construction)
China Guangdong Nuclear Power Group	37
China Datang Corp.	32
China Energy Conservation and Environmental Protection Group (CECEP)	30
Shandong Dahai Group	30 (under construction)
Realforce Power CO.LTD.	30 (under construction)
SDIC Power Holdings CO.LTD.	28
China Huaneng Corp.	20 (under construction)
Gansu province Electric Power Investment Group Corp.	21
Yellow River Hydropower	10
China Huadian Corp.	10
ReneSola Group	10 (under construction)
Grid Power Development CO.LTD.	9
China Power Investment Corp.	9 (under construction)
China Wind Power Group LTD.	9 (under construction)
Tebian Electric Apparatus Stock CO. LTD.	9 (under construction)
China Technology Solar Power Holdings LTD.	5

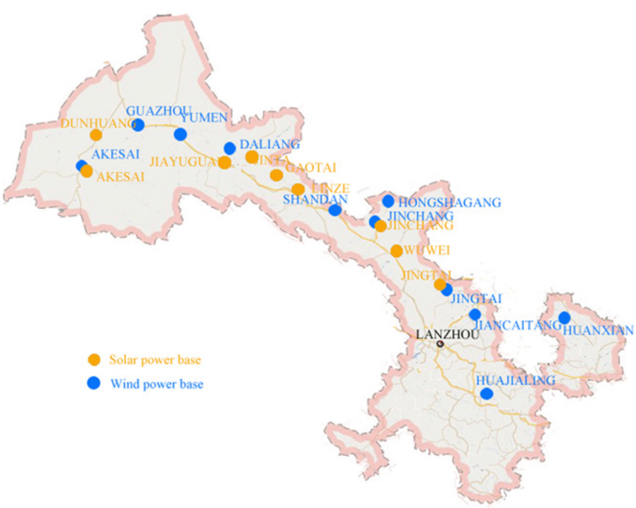

Fig. 8. Locations of primary wind and solar power bases in Gansu [23].

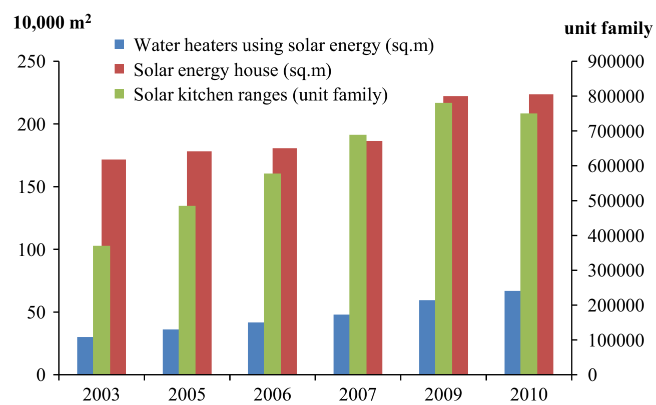

Fig. 9. The development status of solar energy in rural Gansu [3].

5.2.2. Applications of solar energy in rural areas

(1) Solar water heater
Solar water heater is sorted into two types according to their structural form, namely vacuum tube solar water heater and flat plate solar water heater.
Now the former plays a dominant role in domestic market, contributing 95% of overall market share. It is composed of collector tube, water tank and related accessories. Converting solar energy into heat mainly depend on the collector tube who form a micro-circulation of water to produce required hot water by applying the principle that hot water always floats up while cold water sinks down.

(2) Solar house
Solar house can integrate together highly efficient materials with the capability of insulation, light transmission and energy storage through the architectural design. During the day, the sunlight is reflected which help decline the inside temperature, meanwhile solar energy is utilized to heat the air and then store it; at night, the heated air is released hence to reach the heating effect.

(3) Solar stove
Solar stove is a kind of cooking device which concentrates the sun's radiation to acquire heat. It can be basically divided into box solar stove, flat-plate solar stove, concentrating solar stove, indoor solar stove, and energy storage solar stove. The first three sorts all conduct the cooking directly in the sun, while indoor solar stove use heat transfer media to deliver the solar radiation collected from outdoors into indoors. Moreover, energy storage solar stove initially focuses and forces low-grade sunlight turning to high-temperature energy of 800 to 1000 °C on the foundation of optical principles, and then uses the light guide mirror or optical fiber to guide the high-temperature beam directly to stove or just store the energy.

(4) Current development
As shown in Fig. 9, despite the fact that both wind and solar energy in Gansu have undergone a rapid progress, however its renewable energy applications in rural areas are still in a relatively steady or slow pace. The major reasons include rural residents' low income, low level of system maintenance, as well as the discontinuity of government policies [24].

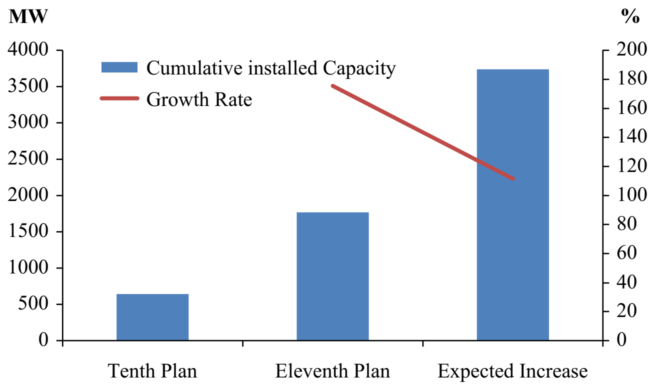

Fig. 10. The development status of small hydropower [26].

5.3. Hydropower

5.3.1. Medium and large-scale hydropower

The exploitation of Gansu's hydropower resource primarily are made up of two parts, one is constructing medium and large-scale hydropower stations with an installed capacity of more than 25 MW, while the other part is building small-scale hydropower stations with under 25 MW size of installed capacity.

At the moment, there are 35 medium and large-scale hydropower stations in Gansu, which shoulder the responsibility for peak shaving, frequency adjustment and emergency standby. Actually, Chinese government once ceased to check and authorize large-scale hydropower projects after 2007 because of environmental and immigrant's troubles, thus national new construction of hydropower stations were merely about 20 million kW during the 11th Five year Plan. Nevertheless, the reality lags a lot behind the 2020 target that non-fossil fuels should make up about 15% of primary energy consumption while the installed capacity of hydropower should reach 350 million kW. Therefore, there is a great possibility that Chinese government will intensify to develop large-scale hydropower project during the 12th Five year Plan. In fact, some news claim that during the 12th Five year Plan, over 60 major hydropower stations will start to construct in the main hydropower bases of China, which also will cover Gansu province [25].

5.3.2. Small-scale hydropower

In China, small-scale hydropower at the present stage refers to hydropower station and its supporting local electricity power supply grid which are set up and managed by local government, group or individual via fund raising, and whose installed capacity is less than 25,000 kW. Actually, in rural areas, small-scale hydropower can replace fuel and provide cheap electricity power, meanwhile it is also conductive to reducing coal and firewood consumption, protecting the forests as well as preventing soil erosion. Gansu's small-scale hydropower resources mainly focus in areas like upstream of Yangtze River and Yellow River, along with the source of Inner River. These areas have sparse population and scattered load while they are difficult to be covered by large grid, hence it is of irreplaceable advantages to develop small-scale hydropower here [25]. During the 11th Five year Plan, Gansu has cumulatively newly increased 230 small and medium-scale hydropower stations, with an installed capacity of 1.126 million kW. By the end of 2010, there are 743 small and medium-scale hydropower stations in provincial total with an overall installed capacity of 2.51 million kW, among which small-scale and medium-scale hydropower stations respectively account for 732 and 11 with an installed capacity of 1.7 and 0.83 million kW. On the other hand, 153 hydropower stations are currently under construction with an installed capacity of 1.97 million kW, among which small-scale and medium-scale hydropower stations respectively are 138 and 15 with an installed capacity of 0.97 and 1 million kW. The development status of small hydropower is shown in Fig. 10 [26].

5.4. Biomass energy

Nowadays in Gansu region, the way of exploiting and utilizing biomass energy primarily contains bio-waste gasification power generation, comprehensive utilization of biomass waste, rural methane project (biogas digester) and so on.

5.4.1. Bio-waste gasification power generation

Bio-waste gasification power generation can be accomplished in three methods. One is that the gasification of biomass yields gas which serves as fuel and is directly put into the gas boiler where steam is generated to drive the steam turbine. One is that transferring the purified gas into the gas turbine to combust and then to generate electricity. Another is that sending the purified gas into the internal combustion engine to generate electricity directly. Moreover, these three methods correspond respectively to large, medium and small-sized electricity generation in terms of generation as well as investment scale.

5.4.2. Comprehensive utilization of biomass waste

Comprehensive utilization of biomass waste means the cycle use of powder residue power and waste water, which process can be describes as following steps. At first, raw materials are conducted secondary ferment to generate three products of biogas for vehicles, methane dregs and methane liquid. Then, methane dregs can produce organic fertilizer while methane liquid can generate highly efficient organic fertilizer and environmentally friendly pesticide. At last, organic fertilizer and pesticide can be used to develop related crops and cultivate its elementary processed products [27].

5.4.3. Rural biogas digester

Biogas is a sort of gas mixture that mainly consists of methane, together with carbon dioxide, hydrogen sulfide, nitrogen and some other materials, among which several gases like methane, hydrogen sulfide, carbon monoxide as well as heavy hydrocarbons are combustible. Biogas digester is a kind of appliance that uses rural biomass waste to ferment and then to produce methane by controlling the temperature, humidity, PH and cutting off oxygen. Nowadays in rural China, four basic types of biogas digester are adopted for household, namely the hydraulic digester, floating cover digester, semi-plastic digester, we well as tank digester.

Actually there are plenty of advantages to use biomass in rural areas. For instance, methane can be utilized directly to provide fuel for cooking, illumination and bathing, while can be also used for grain storage and drying, together with insect control; the use of biogas digesters can cut off the pathogens carried by animals, reducing the source of animal infectious diseases; methane liquid owns the function of sterilization thus can serve as feed additives to improve the disease-resistant ability of animals, meanwhile it can also be utilized for seed soaking to enhance budding rate as well as prevent plant diseases and insect pests; methane dregs can be directly adopted as fertilizer for farmland. [28]

5.4.4. Current development

At present, large-scale industrial uses of biomass energy in Gansu are still in the initial phase, and develop relatively slowly in recent years. In 2006, the straw gasification power generation project invested by the Asian Development Bank was accomplished and put into operation at Shandan, with an installed

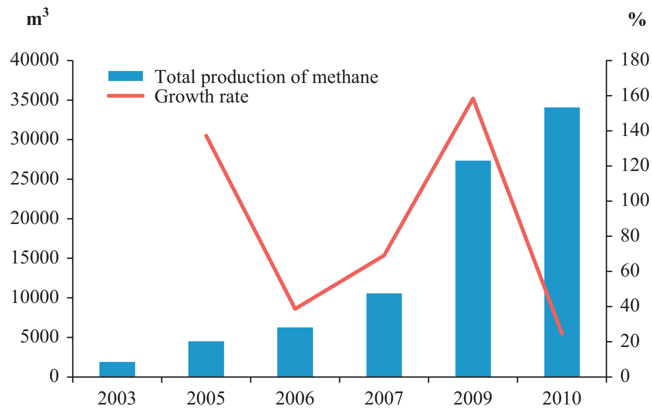

Fig. 11. The year-wise evolution of biogas digester [3].

capacity of 5 MW. This project made 320 families accessed, enjoying a gas pipeline network of 1.6 km, an annual operational time of 4800 h, and a power generation capacity of 0.648 million kWh. Specifically, this project generated 1.12 million kWh of electricity in the period of January to September 2010, and it is still enjoying the national subsidy by now [29].

Wuhan Yangguang Kaidi New Energy Corporation invested two biomass power generation projects in Gansu. One is to construct a 30 MW-sized biomass power plant at Tianshui in 2011, which deployed high-temperature and ultra-high pressure extraction and condensing steam turbine generator unit, and was supported by a similar circulating fluidized bed straw boiler of 120 t per hour. The other one is to invest a biomass power generation project of 30 MW at Wuwei, and it has already started in 2012. Besides, investing ¥225 million in 2009, Gansu built a cycle comprehensive utilization project of potato starch residue as well as waste water. It is estimated that this project can comprehensively utilize 0.3 million tons of potato starch residue every year, while the methane produced by it can reach 200 million m^3 which equals to 0.14 million tons of standard coal.

Owing to the fragile ecology of most Gansu regions and the poverty of its residents, people there depend a lot on biomass resources for living fuel. In the past, Gansu's rural energy supply and demand had a shortage of two months, yet particularly that of the arid, semi-arid and poor regions can be over four to five months. In addition, there were 584 towns with more than 7.1 million people that had an energy shortage of over six months, making up one third of Gansu's rural population. Undoubtedly, developing biomass energy plays a significant role in handling the energy supply issues of Gansu's rural regions [30].

By the end of 2009, the number of Gansu's rural biogas family users had already reached a cumulative total of 0.9 million, while 14 demonstration projects of medium and large-sized methane were accomplished, benefiting 2 million people. Besides, the penetration rate of household methane in administrative villages reached 48%, while that of appropriate farmers increased from less than 1% in 2002 to about 22.5% by then. In the year of 2011, the provincial government of Gansu invested 537.52 million to build 0.1 million new rural biogas digesters for farmers. The year-wise evolution of biogas digester is illustrated in Fig. 11 [3].

6. Challenges

6.1. Wind and solar energy

6.1.1. Technical deficiency

On February 24, 2011, an accident of wind power's large-scale off-grid happened in Jiuquan area of northwest grid, which caused 598 wind turbine units off-grid and lost 840.43 MW electricity power, as well as made the frequency of northwest main grid low down to 49.854 Hz. This accident is the largest in scale, most in loss and widest in influence of all domestic wind power accidents so far [31]. Judging from related investigations, the major technical factors are attributed to three points, namely wind turbine unit's incapability of functioning normally under low voltage, the deficiency of reactive power compensation device, and the improper set of fan frequency protection value. Due to the localization policy of fan, the majority of fans that Gansu install are domestically manufactured, yet there exists several technical deficiencies. For instance, the key design of Chinese wind turbine unit still heavily relies on Europe and the USA, the testing and certification system is not sound and perfect, the own assessment technology of wind resource is still in infancy, the cultivation and reserve of talents is far from being able to meet the requirements of rapid development. Apart from this, China until now has not yet formed unified industry standards such as wind power grid-connecting technology standard and wind turbine testing standard, which is likely to result in the matter of varied operating characteristics under the condition of excessive voltage.

At the moment, Chinese PV cell sector suffers the troubles of blind expansion and reconstruction due to production capacity lag. Some multi-silicon manufactures cannot pass the environmental protection standard, yet still remain open and operating for profits. Moreover, the vast majority of them will consume electricity as high as 180 to 200 kWh to produce one kilogram of multi-silicon. It can be concluded that the lack of core manufacturing technology coupled with high cost will impede multi-silicon sector's further development, which also makes it hard to guarantee the quality of products.

6.1.2. The matter of grid connection and electricity out delivery

Wind and solar power are intermittent, fluctuating and random, hence their generation load are difficult to keep steady. In order to maintain power system's stability, other power sources are required to shoulder the responsibility of adjusting generation load. The centrally dispatched installed capacity of Gansu grid were 14.96 million kW by the end of 2008, yet after considering factors like hydropower and thermal power's operation mode along with corresponding maintenance, the power generation capability that can shoulder wind power's peaking shaving was merely approximately 1.5 million kW which obviously cannot meet the peaking shaving demand of 2010 newly built wind and solar power. Therefore, to keep the stability of the grid, Gansu must rely on the grids of other districts to absorb its wind generated power.

Actually, wind and PV power are undergoing a large scale of development in Gansu, yet the provincial power demand tends to be down. Due to the limited market space, not only Gansu's provincial grid but also the Northwest grid cannot effectively absorb the margin between the demand and supply of wind and PV power [32]. Gansu's cumulative wind power installed capacity is expected to total 12.71 million kW in 2015 while it is supposed to increase to 20 million kW in 2020, and the corresponding wind power generations in these two years are respectively 25 and 42 billion kWh. There is no doubt that these should be absorbed by the nationally overall electricity market.

Unlike the boost of wind power installed capacity in recent years, Gansu's power grid develops relatively slowly. For example, as for the 10 million kW scale of wind power base in Jiuquan region, Hexi's 330 kV-size power grid cannot satisfy need of sending out current wind power. Furthermore, Hexi's conventional 750 kV-size power grid is now capable of transferring

electricity from west to the east at a size of about 1.8 million kW, which will still be only 3.18 million kW even after adopting several world widely most advanced technologies like 750 kV series compensation and 750 kV controllable high resistance measurements(they are not available in China at the present), coupled with interconnecting with Xinjiang's grid to enhance the stability level and transmission ability of power system. However, a transmission ability of 3.18 million kW can merely send out 94% of the wind power generated by the end of 2010 [32].

6.1.3. Cost effectiveness

The wind and solar power develop so rapidly which bring about a series of issues to their power projects. First of all, domestically manufactured wind turbine units and solar cells have quality risks, and accidents such as fan being off the grid will cause heavy losses to the power generation enterprises and impact the power grid as well. Secondly, there are several problems of plants' operation as well as management which would likely to increase their operational cost. For instance, the setting of wind power operating standard is lagging behind; production and operation personnel lack of knowledge and experience; the regulations and standards about the operational safety and quality of wind farm are incomplete. Thirdly, the construction costs of wind and PV power are still a little high whereas the tariffs are low in contrast, which makes great pressure on their cost recovery. Taking the 0.2 million kW of wind concession project in Changma wind power plant of Jiuquan wind power base as an example, this project's whole investment internal rate of return is 6.54% which fails to reach the 8% benchmark of electricity power industry [33]. But even so, the price of electricity generated by renewable energy is not that competitive in contrast to that of fossil energy, while a number of renewable energy generation projects are still counting on government subsidies. Finally, there exists a lot of blindness in the investment of wind and PV power projects in that some investments are even without considering the development potential or carrying out prudent resource measurement, which leads to the location of some power plants in resource-poor areas and then a further restriction of expected return.

6.1.4. Monotony of utilization ways

At the moment, the utilization way of wind and solar energy primarily is constructing large-sized grid-connected power plants, yet other methods are underdeveloped. Taking the rooftop use of solar energy as an example, the Chinese central government began to encourage this sector early in 2009, but it still lags behind now for its unformed industrial scale and standards, uncertain tariff, insufficient people's awareness and unclear administrative approval processes [34].

All in all, Gansu's wind and solar power generation has technical risks. Meanwhile, it faces the trouble of excess production capacity that cannot be absorbed by local grid or transferred out, which then could lead to the abandonment of some RES. What's more, these issues are not unique in Gansu province, but are also shared by other northwestern provinces of China such as Ningxia and Inner Mongolia [35].

6.2. Hydropower

In recent years, medium and large-sized hydropower plants in Gansu develop relatively slowly and confront the risks of uneven precipitation and environmental damage, whereas small-sized hydropower plants enjoy a booming and face a lot more challenges owing to its rapid progress.

Lacking of normalized policies and regulations, the formulation of small-sized hydropower price more or less reveals the subjectivity of the decision-makers. Together with the monopoly of state-owned large grid company on transmission and distribution rights, small-sized hydropower price always is pressured to very low level [36]. According to the survey on the cost of all rural small-sized hydropower plants in the 8th, 9th and 10th Five Year Plan, their power generation cost is about 0.17 ¥/kWh and it is likely to be 0.28–0.35 ¥/kWh after adding the taxation and a reasonable profit, yet in fact the tariff of Gansu's present small hydropower is merely between 0.18 and 0.22 ¥/kWh.

After Chinese central government opened the small-sized hydropower market to private capitals, some local governments loosen the supervision in order to pursuit short-term interests, therefore bringing about many disorderly development matters. In particular, to seize the resources, a great number of private developers rushed to construct the hydropower plants even without sufficient plan and preparatory work, or any evaluation and assessment of environmental impact and geological disaster. Moreover, these small-sized hydropower plants majorly are water diversion power plant, therefore the rush investments may cause the unreasonable convergence of normal water level at each cascade of small tributary and even river blanking, which eventually exerts devastating damage to the geology and ecology of river channels. In particular, extremely serious debris flow disaster happened in Zhouqu in the year of 2010, causing over 1000 people dead and towns basically destroyed. Nevertheless, Zhouqu began to develop small-sized hydropower plants merely one year after the disaster in 2011, while 67 of them are without approval. Obviously, some unqualified developers also took part in this industry because of the rapid development and insufficient supervision, bringing about a great number of quality and safety risks.

The rapid and disorderly development of Gansu's small-sized hydropower leads to environmental pollution, quality and safety risks, as well as a large amount of social cost. Meanwhile, the tariff is too low to achieve expected cost effectiveness. The exploitation of many hydropower plants depend on bank and private loans, so financial risk may be brought about if the project benefits are not ensured, which then would further increase its social cost. At last, excessively high social cost is probably to offset or even exceed the social benefit that small-sized hydropower brings.

6.3. Biomass energy

In Gansu, large-sized biomass power grid-connecting projects are still in its initial stage, yet their potential challenges can be concluded based on the experience of other provinces. Firstly, the scale of raw material industry is small and it is scattered, thus the purchasing cost is expensive. Secondly, the regulations and policies are incomplete and lacks of detailed rules, hence it is hard to operate. Thirdly, core technologies are very much scarce and desperately needed [28]. In fact, the majority of these projects are going through a difficult period, while having trouble in profits. Taking Guoxinrudong Biomass Power Generation Company of Jiangshu province as an example which is a demonstration project of biomass power generation at the national level, it has fell into a vicious cycle that financial losses increase with more generation of electricity power since its operation in July 2008, and it has already lost as much as ¥15 million in half an year's time [37].

6.4. The development of renewable energy in rural areas

Nowadays, Gansu's rural utilization and development of renewable energy is at a relatively fast pace, including solar

water heater, solar house, solar stove, and rural methane project. However, there are still several challenges to face. For one thing, farmers and herdsmen show not that much enthusiasm in investment on renewable energy devices duo to their low paying capability. For another, non-professional equipment maintenance and discontinuous government policies shorten the lifecycle of many renewable energy devices and then greatly discounts their usage value [24], for example biogas digesters usually have low utilization rate and efficiency due to the influences of winter low temperature, poor construction quality as well as unsatisfactory management effectiveness [38]. According to a research in the western provinces in China, there exist some other problems in the electrification in rural areas: electricity generation capacity and quality are required to be standardized; system quality control is still weak; operation and maintenance of village power system requires enhancement; ownership and management responsibility of renewable energy power system are unclear; the tariff collection is haphazard [39], which can also be seen in the renewable energy deployment in Gansu.

7. Conclusion

Gansu province is a proper representative of China's northwestern areas in geographic location, economy development, RES reserve and development. Nevertheless, its sustainable development is now going through a challenging period due to its weak ecology and long-time economic dependence on high energy-consumption industries. Given that Gansu is abundant in wind energy, solar energy, hydropower, and biomass energy, hence its development of renewable energy is of great significance to its both economy growth and sustainable development.

Currently, large grid-connected wind and solar power plants have been undergoing a rapid flourish, yet still are confronting enormous challenges in various aspects such as generation technology, plant planning, operation and management, grid stabilization, along with electricity out delivery. Consequently, it is imperative to adopt several strategies to handle the problems:

- Enhancing the independent technical R&D of domestic upstream manufactures in renewable energy industry and improving production quality.
- Imposing more strict restrictions on the examination and approval procedures of renewable resource projects in this district.
- Introducing specific industrial standards as soon as possible.
- Strengthening the R&D of grid technology and improving power grid's capability of electricity absorption as well as out delivery.
- The development of small hydropower in Gansu is also booming, whereas similarly faces many troubles like technology shortage, excessively low feed-in tariff, disorderly exploiting plan and so on. Hence, following strategies are of significant reference value:
- Normalizing related industries and establishing strict qualification review system of equipment producer and developer.
- Carrying out more benefiting pricing mechanism.
- Conducting more prudent planning and project verification procedures.

The development of renewable energy in Gansu's rural area is rather fast, but it is strongly driven by government policy. Besides, rural residents usually have little enthusiasm and the equipment suffer severe depreciation. Therefore, it is suggested to further enhance their income, introduce more continuous policy system, and supervise more strictly on equipment quality.

All in all, it can be concluded that although the renewable energy of Gansu is developing in a fast speed, it is too dependent on government policies to balance demand and supply, technology and production, electricity generation and transmission, along with resource and development, which may be the very essential challenge for the future development of renewable energy in China.

Acknowledgments

The authors would like to acknowledge the supports by the Chinese National Nature Science Foundation of China (No. 71271085) and Beijing Twelfth Five Year Plan Project of philosophy and social sciences (No. 12JGB044).

References

[1] China Statistical Yearbook (CSYB) 2001–2008. Beijing:China Statistics Publications;2001–2008.
[2] Wenqin Li. Gansu's ecological environment construction and regional economic sustainable development. Journal of Lanzhou University (social sciences) 2005;33(3):15–9.
[3] Gansu Statistical Yearbook 2004–2009. Gansu:China Statistics Publications;2004–2009.
[4] Wang Xiaowen, Liu Huanhuan. Pollution haven hypothesis-Practical considerations in western less developed areas-taking Gansu as an example. Journal of Graduate School of Chinese Academy of Social Sciences 2009;6:52–62.
[5] Yu Li, Qiang Zhang. Heavy metal pollution and sources of Irrigation and rain-fed agricultural soils in central Gansu. Journal of Lanzhou University (Natural Sciences) 2011;6:56–61.
[6] Xiaowen Wang, Jing Yi. Research on the sustainable development of Gansu's ecological economy based on ecological footprint. Journal of Gansu Social Science 2010;3:206–8.
[7] Wind Resources Distribution Analysis. Beijing:China Meteorological Administration;2007.
[8] National solar resource map of Gansu. Beijing:China Meteorological Administration;2011.
[9] Land resource map set of Gansu. China Cartographic Publishing House;2011.
[10] Aigong Qiao. The current status and sustainable development of hydropower in Gansu. Journal of Investigation and Research 2007;9:86–7.
[11] Zhongcun Pang, Yongmao Zhang. Current Situation and Countermeasures of biomass waste's cycle utilization. Journal of Rural Energy Construction 2009;4:25–6.
[12] The medium and long-term program of renewable energy development. Beijing:China National Development and Reform Commission;2007.
[13] Renewable Energy Law. Beijing:China State Council;2006.
[14] Luo Chunjun. Brief research on the feed-in tariff of hydropower. Hunan hydropower electricity 2010;2:97–100.
[15] Temporary management method of electricity price and cost-sharing of renewable energy power generation. Beijing:China National Ministry of Finance;2006.
[16] Temporary management method of the special fund for wind power generation equipment industrialization. Beijing:China National Ministry of Finance;2008.
[17] Temporary management method of price subsidy for Golden Sun demonstration projects. Beijing:China National Ministry of Finance, Ministry of Science and Technology, Energy Administration;2009.
[18] Qiang Wang. Effective policies for renewable energy—the example of China's wind power—lessons for China's photovoltaic power. Renewable and Sustainable Energy Reviews 2010;14:702–12.
[19] Development and Reform Commission of Gansu. Available from:〈http://www.gspc.gov.cn/〉;2010.
[20] China wind power outlook 2011. Chinese environmental industry press;2011.
[21] The sequential electric trade increment of 2010. Power exchange center of Gansu electric power corporation. Available from:〈http://61.178.40.7/item/369.aspx〉;2010.
[22] Ren Dongming, Tao Ye, Zhao yongqiang, Hu runqing, Qin shiping. Analysis on the problems of the 10 MW PV power concession demonstration project. Sino-Global energy 2011;16:31–5.
[23] Map of Gansu. Google map service. Available from:〈http://ditu〉. google.cn.
[24] Li Dan, Pen Jun, Yu Yuefeng. The application of energy contract management model in off-grid electricity use. Electric Power 2008;41:76–80 [in Chinese].
[25] Qiao Aigong. The current status and sustainable development of hydropower in Gansu. Fazhan 2007;9:86–7.
[26] Yan Youyong. Strongly and orderly developing hydropower to support the New Countryside construction. China water power and electrification 2011;71:113–7.

[27] Zhang Quanyou, Li Rubing. Exploiting and operating biomass energy industrial project in modern way. Sino-global enterpriser 2011;11:61–2.

[28] Zhou Xiaoling. Thoughts about the development of biomass energy in China. Renewable energy resource 2011;29(2):141–3.

[29] The website of Chinese National Development and Reform Commission. Available from:http://www.google.com.hk/url?sa=t&rct=j&q=site:http%3A%2F%2Fwww.sdpc.gov.cn%2F++%E5%8F%AF%E5%86%8D%E7%94%9F+%E8%A1%A5%E8%B4%B4&source=web&cd=1&ved=0CC8QFjAA&url=http%3A%2F%2Fwww.sdpc.gov.cn%2Fzcfb%2Fzcfbtz%2F2011tz%2FW020110215329731601268.pdf&ei=6O2DT_-TGJILeigfw1ryxBw&usg=AFQjCNFlgVNb-DV_D76aKmSbWIacZS_YVA;2010.

[30] Yuan Fengxiang. Promoting Gansu's biogas in a scientific development concept. New energy industry 2011:14–8 [in Chinese].

[31] Xiang Yi, Sun Xiaoqiang, Zhang Xiaoqi, Duan Naixin. The problems exposed in the accident of a large number of wind power generators get offline on Feb. 24th 2011. North China Electric Power 2011;9:1–7.

[32] Wang Ningbo. Challenges and countermeasures of the 10 million kW wind power base in Jiuquan. Wind energy 2010;2:41–3 [in Chinese].

[33] Gao Wei, Zhang Penglin, Jinpeng Yang, Haofeng Liang, Ying Guo. Analysis on cost effectiveness of wind power industry in Gansu. Financial research 2011;14:53–6 [in Chinese].

[34] Yi Yingqun. The current application and potential promotion of solar energy's rooftop use in China. Pulic Electricity 2010;12:17–9.

[35] Li Xiumeng. Analysis on the wind power industry in Ningxia. Wind energy 2011;12:38–41 [in Chinese].

[36] Zheng Qiong, Shang Jin. Analysis on the challenges and opportunities faced by local small hydropower. Journal of Chongqing University of Science and Technology 2010;13:97–9.

[37] Gao Li, Mer Yingdan. The current situation and existing problems of our country's biomass power generation industry. Ecological Economy 2011;8:123–7.

[38] Mao Jianbin. Thoughts about the development and application of renewable energy in rural areas. Gansu Agriculture 2011;54:7–8.

[39] Xilin Zhang, Ashok Kumar. Evaluating renewable energy-based rural electrification program in western China: emerging problems and possible scenarios. Renewable and Sustainable Energy Reviews 2011;15:773–9.